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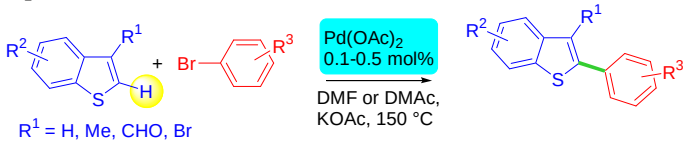

R^1 = H, Me, CHO, Br

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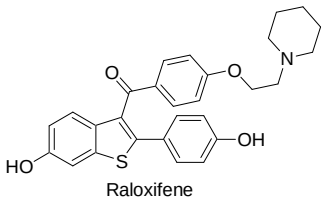
Abstract— Ligand-free $Pd(OAc)_2$ was found to catalyze very efficiently the direct C2-arylation of benzothiophene derivatives under low catalyst concentration. The reaction can be performed employing as little as 0.5-0.1 mol-% catalyst with electron-deficient and some electron-rich aryl bromides. The presence of a methyl or a formyl substituent at C3 of benzothiophene has a minor influence on the reactivity, and even a bromo substituents at C3 is tolerated. A wide variety of functional groups on the aryl bromide such as nitrile, nitro, acetyl, formyl, ester, chloro, fluoro or trifluoromethyl has been employed.

Keywords: palladium, catalysis, C-H bond functionalization, benzothiophenes, aryl bromides

1. Introduction

Benzothiophene derivatives are of considerable interest for pharmaceutical chemistry due to their biological activities. For example, the 2-arylbenzothiophene derivative Raloxifene is used in the prevention of osteoporosis (Figure 1). Therefore, the development of simple and convenient processes using readily accessible benzothiophene derivatives for the synthesis of arylated benzothiophenes is highly desirable.



Raloxifene

Figure 1. Example of bioactive 2-arylbenzothiophene.

The palladium-catalyzed direct arylation of several heteroaromatics such as furans, thiophenes or pyrroles *via* a C–H bond activation using aryl halides has led to successes in recent years.[1-5] Such couplings are very attractive compared to classical palladium-catalysed reactions such as Stille, Suzuki or Negishi couplings[6] as they do not require the preliminary synthesis of organometallic derivatives. Some examples of such direct arylations using benzothiophenes have also been reported.[7,8] However, the reported procedures either require 1-10 mol-% palladium catalyst associated to 1-20 mol-% of phosphine ligands[7] or employed a stoichiometric amount of quaternary ammonium salts or crown ethers as stabilizing agents producing important amount of wastes.[8] To our knowledge, the palladium-catalysed direct arylation of benzothiophenes using ligand-free catalyst without stabilizing agent have not been reported to date. The use of such conditions would be very attractive for industrial application, as it would reduce both the cost and wastes formation of such couplings.

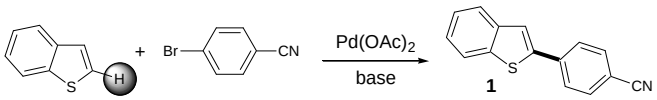
In 2003, de Vries and co-workers have described extremely exciting results for the Heck and Suzuki reactions using a low loading (0.1-0.01 mol-%) of ligand-free catalyst $Pd(OAc)_2$.[9] They have demonstrated that, at elevated temperature, when $Pd(OAc)_2$ is employed as the catalyst precursor, soluble palladium(0) colloids or nanoparticles are formed, and that the Heck or Suzuki reaction takes place. We have recently reported that the use of the "de Vries conditions" allows the coupling or several heteroaromatics such as pyrroles,[10c] imidazoles,[10d] furans,[10e] thiophenes[10e] or imidazopyridines[10f] using a very low loading (0.1-0.01 mol-%) of ligand-free $Pd(OAc)_2$ catalyst.[10] However, so far, such procedure has not been employed for the direct arylation of benzothiophenes.[11]

Here, we wish to report on the coupling of benzothiophene derivatives with a variety of electronically and sterically diverse aryl and heteroaryl bromides using low loadings of ligand-free $Pd(OAc)_2$ catalyst.

2. Results and discussion

First, we examined the influence of the reaction conditions for the coupling of benzothiophene with 4-bromobenzonitrile (Scheme 1, Table 1). Starting form a slight excess of benzothiophene (1.5 eq.) with respect to the aryl bromide, in the presence of 0.5 mol-% $Pd(OAc)_2$ as the catalyst, KOAc as the base, and DMAc as the solvent at 150 °C, the desired product **1** was obtained in 69% yield; whereas, a lower catalyst loading of 0.1 mol-% gave **1** in only 55% yield due to an uncomplete conversion of the aryl

bromide (Table 1, entries 1 and 2). The influence of a few other bases was also examined; however, NaOAc, CsOAc, KF or carbonates led to lower yields of **1** (Table 1, entries 3-8). Then, we explored the influence of a few other solvents. Moderated yields were obtained in diethyl carbonate or cyclopentyl methyl ether (Table 1, entries 11 and 12). On the other hand, the use of only 0.1 mol-% $Pd(OAc)_2$ in DMF gave **1** in 59% yield (Table 1, entry 9).



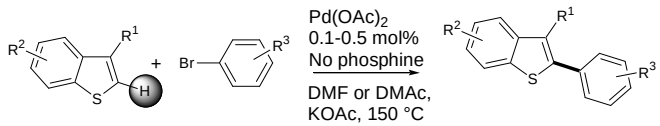
Scheme 1. Palladium-catalysed direct C2-arylation of benzothiophene with 4-bromobenzonitrile.

Table 1. Influence of the reaction conditions for palladium-catalysed direct C2-arylation of benzothiophene with 4-bromobenzonitrile (Scheme 1).

Entry	$Pd(OAc)_2$ (mol-%)	Solvent	Base	Conv. (%)	Yield in **1** (%)
1	0.5	DMAc	KOAc	100	69
2	0.1	DMAc	KOAc	67	55
3	0.1	DMAc	CsOAc	12	-
4	0.1	DMAc	NaOAc	43	37
5	0.1	DMAc	Na_2CO_3	25	18
6	0.1	DMAc	K_2CO_3	7	6
7	0.1	DMAc	Cs_2CO_3	90	0[a]
8	0.1	DMAc	KF	36	30
9	0.1	DMF	KOAc	80	59[b]
10	0.5	NMP	KOAc	70	55[b]
11	0.5	diethyl carbonate	KOAc	54	48[b]
12	0.5	cyclopentyl methyl ether	KOAc	51	42[b]
13	0.5	pentan-1-ol	KOAc	10	-[b]

[a] $Pd(OAc)_2$, 4-bromobenzonitrile (1 mmol), benzothiophene (1.5 mmol), base (2 mmol), 150 °C, 16 h, under argon, conversion of 4-bromobenzonitrile. [a] Formation of 4-bromobenzamide. [b] Catalyst is a solution prepared with 1 mg of $Pd(OAc)_2$ in 1 mL of DMAc.

We then studied the scope of 2-arylation of benzothiophene using 0.1 or 0.5 mol-% $Pd(OAc)_2$ catalyst, KOAc as the base and either DMF or DMAc as the solvent (Scheme 2, Table 2). A good yield in **4** was obtained from 4-bromobenzaldehyde using only 0.1 mol-% $Pd(OAc)_2$ (Table 2, entry 4). However, in most cases, 0.5 mol-% $Pd(OAc)_2$ had to be employed to observe high conversions of the aryl bromides and good yields of coupling products. For example, with this catalyst loading, 4-trifluoromethylbromobenzene, 4-bromoacetophenone, ethyl 4-bromobenzoate, 4-chlorobromobenzene or 4-fluorobromobenzene gave the expected C2-arylated benzothiophenes **3**, **5**-**8** in 61-80% yields (Table 2, entries 3, 5-12). With these reactants, very similar yields were obtained using DMF or DMAc as the solvent. It should be noted that no cleavage of the C-Cl bond of 4-chlorobromobenzene was observed under these reaction conditions allowing further transformations. In the presence of the electron-rich aryl bromides, 4-bromotoluene and 4-*tert*-butylbromobenzene, moderate yields in **9** and **10** were obtained, due to partial conversion of these aryl bromides (Table 2, entries 13 and 14).



Scheme 2. Palladium-catalysed direct arylation of benzothiophene derivatives with (hetero)aryl bromides.

Table 2. Palladium-catalysed arylation of benzothiophene with (hetero)aryl bromides (Scheme 2).

Entry	Aryl halide	Product	Catalyst (mol-%)	Yield (%)
1	O_2N–Br	O_2N– **2**	0.1	51
2	F_3C–Br	F_3C– **3**	0.1	22
3			0.5	61
4	O, Br	O, **4**	0.1	72
5	O, Br	O, **5**	0.5	66
6			0.5	63[a]
7	O, EtO, Br	O, EtO, **6**	0.5	76
8			0.5	77[a]
9	Cl–Br	Cl– **7**	0.5	73
10			0.5	71[a]
11	F–Br	F– **8**	0.5	80
12			0.5	73[a]
13	Me–Br	Me– **9**	0.5	55
14	*t*Bu–Br	*t*Bu– **10**	0.5	32
15	NC, Br	NC, **11**	0.1	60
16	Br	**12**	0.5	60
17	Br	**13**	0.1	62
18	CN, Br	CN, **14**	0.1	73
19	Br	**15**	0.5	82[a]
20	Br	**16**	0.5	trace
21			0.5	83[a]
22	N, N, Br	N, N, **17**	0.1	66

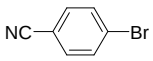
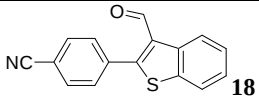
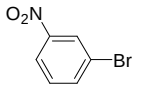
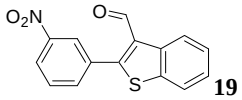
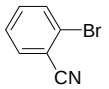
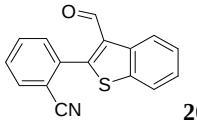
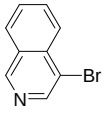
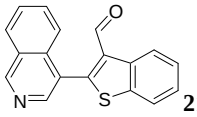
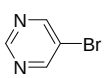
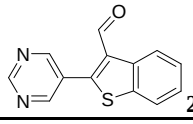
Conditions: Catalyst is a solution prepared with 1 mg of $Pd(OAc)_2$ in 1 mL of DMAc (0.001 or 0.005 eq.), benzothiophene (1.5 eq.),

aryl bromide (1 eq.), KOAc (2 eq.), DMF, 150 °C, 16 h, isolated yields. [a] Solvent: DMAc.

With such substrates, the use of palladium associated to phosphine ligands should be preferred. A few *meta*- and *ortho*-substituted aryl bromides were also employed. 2- and 3-bromobenzonitriles gave **11** and **14** in 60% and 73% yields, respectively in the presence of 0.1 mol-% $Pd(OAc)_2$ (Table 2, entries 15 and 18). Both 1- and 2-bromonaphthalene gave the expected products **15** and **13** (Table 2, entries 17 and 19). However, from 1-bromonaphthalene, a higher yield in **15** was obtained when using DMAc as the solvent. A similar tendency was observed with 9-bromoanthracene. In DMF, a very low yield in **16** was observed by GC/MS analysis due to the formation of several unidentified side-products; whereas a very clean reaction was observed in DMAc to give **16** in 83% yield (Table 2, entries 20 and 21). Therefore, for challenging aryl bromides, the use of DMAc as the solvent should be preferred. We also examined the coupling of 5-bromopyrimidine with benzothiophene. The desired product **22** was isolated in 66% yield (Table 2, entry 22). For all these reactions, no arylation at C3 of benzothiophene was detected.

We then studied the reactivity of benzothiophene-3-carbaldehyde with some aryl bromides (Table 3). We observed that using 0.1 mol-% $Pd(OAc)_2$ as the catalyst and 4-bromobenzonitrile as coupling partner in DMF, the 2-arylated benzothiophene **18** was obtained in low yield (Table 3, entry 1). Moreover, the formation of the homocoupling product biphenyl-4,4'-dicarbonitrile was also observed.

Table 3. Palladium-catalysed C2-arylation of benzothiophene-3-carbaldehyde with (hetero)aryl bromides (Scheme 2).

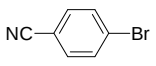
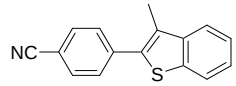
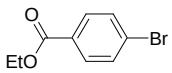
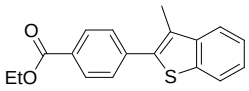
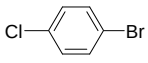
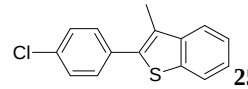
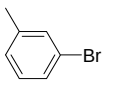
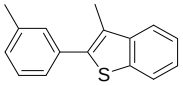
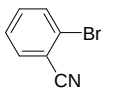
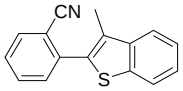
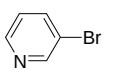
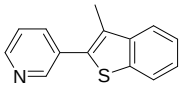
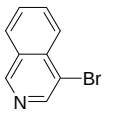
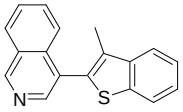
Entry	Aryl halide	Product	Catalyst (mol-%)	Yield (%)
1		 **18**	0.1	13[a]
2			0.5	33[a]
3			0.5	65
4		 **19**	0.5	78
5		 **20**	0.5	77
6		 **21**	0.5	65
7		 **22**	0.5	61

Conditions: benzothiophene-3-carbaldehyde (1.5 eq.), aryl bromide (1 eq.), KOAc (2 eq.), DMAc, 150 °C, 16 h, isolated yields. [a] In DMF with a solution of catalyst prepared with 1 mg of $Pd(OAc)_2$ in 1 mL of DMAc.

The use of a higher catalyst loading allowed to improve the yield in **18** to 33%, but some formation of unidentified side-products was observed, and again, some formation of biphenyl-4,4'-dicarbonitrile was detected (Table 3, entry 2). On the other hand, in DMAc, using 0.5 mol-% $Pd(OAc)_2$, a clean reaction was observed, and **18** was isolated in 65% yield (Table 3, entry 3). The stability of benzothiophene-3-carbaldehyde in DMF appears to be limited. From the more congested substrate 2-bromobenzonitrile, a good yield in **20** was also obtained in DMAc (Table 3, entry 5). A similar reactivity of 3-bromonitrobenzene, 4-bromoisoquinoline or 5-bromopyrimidine was observed in DMAc to give **19**, **21** and **22** in 61-78% yields (Table 2, entries 4, 6 and 7).

With 3-methylbenzothiophene in DMAc, very clean reactions were observed in all cases using various aryl bromides and 0.1-0.5 mol-% $Pd(OAc)_2$ catalyst (Table 4). The electron-deficient aryl bromides, 4-bromobenzonitrile and ethyl 4-bromobenzoate gave **23** and **24** in 88% and 81% yields, respectively using 0.5 mol-% $Pd(OAc)_2$ catalyst (Table 4, entries 1 and 2). A high yield in **25** resulting from selective cleavage of the C-Br bond was also obtained from 4-chlorobromobenzene (Table 4, entries 3 and 4). The use of only 0.1 mol-% $Pd(OAc)_2$ led to a high conversion of this aryl bromide.

Table 4. Palladium-catalysed C2-arylation of 3-methylbenzothiophene with (hetero)aryl bromides (Scheme 2).

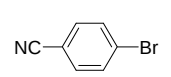
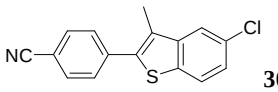
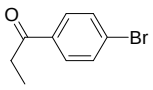
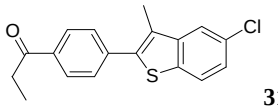
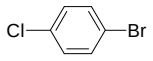
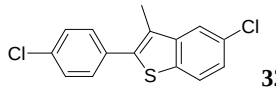
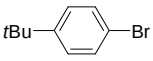
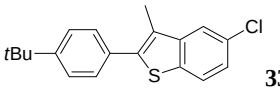
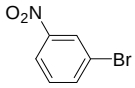
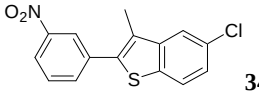
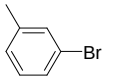
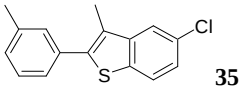
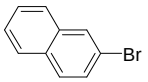
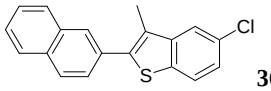
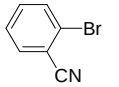
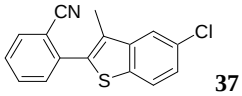
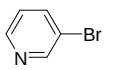
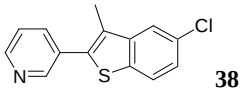
Entry	Aryl halide	Product	Catalyst (mol-%)	Yield (%)
1		 **23**	0.5	88
2		 **24**	0.5	81
3		 **25**	0.1	72
4			0.5	88
5		 **26**	0.5	66
6		 **27**	0.5	79
7		 **28**	0.1	70
8		 **29**	0.1	61

Conditions: $Pd(OAc)_2$ (0.001 or 0.005 eq.), 3-methylbenzothiophene (1.5 eq.), aryl bromide (1 eq.), KOAc (2 eq.), DMAc, 150 °C, 16 h, isolated yields.

Again, no cleavage of the C-Cl bond was observed allowing further transformations. A slightly lower yield was obtained for the coupling of the electron-rich aryl bromide: 3-bromotoluene (Table 4, entry 5). It should be noted that both 3-bromopyridine and 4-bromoisoquinoline could be coupled with 3-methylbenzothiophene to give **28** and **29** in high yields using only 0.1 mol-% $Pd(OAc)_2$ (Table 4, entries 7 and 8).

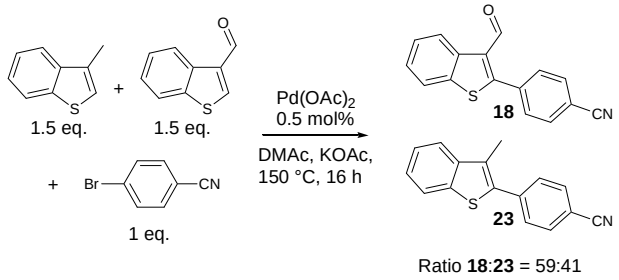
The reactivity of 5-chloro-3-methylbenzothiophene with a set of (hetero)aryl bromides was also examined using 0.1-0.5 mol-% $Pd(OAc)_2$ catalyst (Table 5). In all cases, high yields of the desired coupling products **30**-**38** were obtained, except with the electron-rich, 4-*tert*-butylbromobenzene. For example, from 4-chlorobromobenzene, 3-nitrobromobenzene or 2-bromobenzonitrile and 0.1 mol-% $Pd(OAc)_2$, the products **32**, **34** and **37** were obtained in 82-85% yields (Table 5, entries 3, 5 and 8).

Table 5. Palladium-catalysed C2-arylation of 5-chloro-3-methylbenzothiophene with (hetero)aryl bromides (Scheme 2).

Entry	Aryl halide	Product	Catalyst (mol-%)	Yield (%)
1		 **30**	0.5	78
2		 **31**	0.5	83
3		 **32**	0.1	85
4		 **33**	0.1	58
5		 **34**	0.1	83
6		 **35**	0.5	80
7		 **36**	0.1	88
8		 **37**	0.1	82
9		 **38**	0.1	76

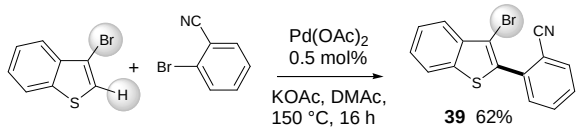
Conditions: $Pd(OAc)_2$ (0.001 or 0.005 eq.), 5-chloro-3-methylbenzothiophene (1.5 eq.), aryl bromide (1 eq.), KOAc (2 eq.), DMAc, 150 °C, 16 h, isolated yields.

In order to have a better insight of the influence of the benzothiophenes C3-substituents on their reactivity, we performed a competitive experiment using an equimolar mixture of 3-methylbenzothiophene and benzothiophene-3-carbaldehyde in the presence of 4-bromobenzonitrile and 0.5 mol-% $Pd(OAc)_2$ (Scheme 3). We observed the formation of a mixture of the products **23** and **18** in a 41:59 ratio. This result indicates that the presence of electron-donating or electron-withdrawing substituents at C3 of benzothiophenes only has a minor influence on their reactivity.



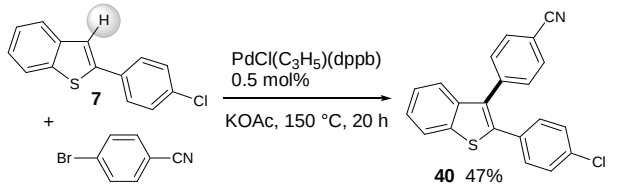
Scheme 3. Competitive experiments using a mixture of 3-methylbenzothiophene and benzothiophene-3-carbaldehyde.

To our knowledge, the direct arylation at C2 of 3-bromobenzothiophene has not been reported. So far, the coupling of such reactants to prepare 3-arylbenzothiophenes employs organozinc intermediates.[12] We observed that using 3-bromobenzothiophene and 2-bromobenzonitrile in a 1.5:1 ratio and again 0.5 mol-% $Pd(OAc)_2$ catalyst, the desired product **39** was obtained in 62% yield without cleavage of the C-Br bond of the benzothiophene derivative.



Scheme 4. Palladium-catalysed direct arylation of 3-bromobenzothiophene with 2-bromobenzonitrile.

Finally, the palladium-catalysed C3 direct arylation of **7** was examined (Scheme 5). The use of 0.5 mol-% $Pd(OAc)_2$ catalyst gave **40** as traces. On the other hand, in the presence of 0.5 mol-% $PdCl(C_3H_5)(dppb)$ catalyst, **40** was isolated in 47% yield, without cleavage of the C-Cl bond of the aryl substituent, showing the beneficial effect of the phosphine ligand in this case.



Scheme 5. Palladium-catalysed direct C3 arylation of 2-arylbenzothiophene **7** with 4-bromobenzonitrile.

In summary, we have demonstrated that using as little as 0.5-0.1 mol-% of $Pd(OAc)_2$ as the catalyst precursor, the direct 2-arylation via C-H bond activation of benzothiophenes proceeds in moderate to high yields. This procedure gave the best results using electron-deficient aryl bromides. Several functions such as formyl, acetyl, propionyl, nitro, nitrile, chloro, fluoro or trifluoromethyl are tolerated. Congested aryl bromides such as 9-bromoanthracene, also gave satisfactory results. This ligand-free low catalyst loading procedure is economically and environmentally attractive, as there is no need to eliminate phosphine derivatives at the end of the reaction; and as with this C-H bond activation procedure, no preparation of an organometallic derivative is required, reducing the number of steps and therefore the mass of waste products. The major waste is the relatively non-toxic AcOH/KBr instead of metallic salts with more classical metal-catalysed coupling reactions. For these reasons, the methodology developed here is very promising for the sustainable synthesis of 2-arylbenzothiophenes.

3. Experimental

General: All reactions were performed in Schlenck tubes under argon. Potassium acetate 99+ was used. Benzothiophenes and aryl bromides were used without purification. ^1H (400 MHz, 25 °C), ^{13}C (100 MHz, 25 °C) spectra were recorded in $CDCl_3$ solutions. Chemical shifts are reported in ppm relative to $CDCl_3$ (^1H: 7.29 and ^{13}C: 77.0). Flash chromatography was performed on silica gel (230-400 mesh).

General procedure for the preparation of 1-40:
As a typical experiment, the reaction of the aryl bromide (1 mmol), benzothiophene (1.5 mmol) and KOAc (0.196 g, 2 mmol) at 150 °C during 16 h in DMF or DMAc (4 mL) in the presence of $Pd(OAc)_2$ (0.224 mg, 0.001 mmol) or (1.12 mg, 0.005 mmol) prepared as a solution in DMAc (1 mg of $Pd(OAc)_2$ in 1 mL of DMAc) under argon affords the coupling product after evaporation of the solvent and purification on silica gel.

2-(4-Cyanophenyl)-benzo[b]thiophene (1)[7l]
From 4-bromobenzonitrile (0.182 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **1** was obtained in 69% (0.162 g) yield. ^1H NMR (400 MHz, $CDCl_3$): δ 7.76 (d, *J* = 8.1 Hz, 1H), 7.72 (d, *J* = 7.9 Hz, 1H), 7.68 (d, *J* = 8.4 Hz, 2H), 7.59 (d, *J* = 8.4 Hz, 2H), 7.55 (s, 1H), 7.30 (t, *J* = 7.3 Hz, 1H), 7.28 (t, *J* = 7.3 Hz, 1H).

2-(4-Nitrophenyl)-benzo[b]thiophene (2)[7l]
From 4-bromonitrobenzene (0.202 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **2** was obtained in 51% (0.130 g) yield. ^1H NMR (400 MHz, $CDCl_3$): δ 8.20 (d, *J* = 8.4 Hz, 2H), 7.82-7.70 (m, 4H), 7.64 (s, 1H), 7.33 (t, *J* = 7.3 Hz, 1H), 7.31 (t, *J* = 7.3 Hz, 1H).

2-[4-(Trifluoromethyl)phenyl]-benzo[b]thiophene (3)[7j]
From 1-bromo-4-trifluoromethylbenzene (0.225 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **3** was obtained in 61% (0.170 g) yield. ^1H NMR (400 MHz, $CDCl_3$): δ 7.80-7.70 (m, 4H), 7.61 (d, *J* = 8.2 Hz, 2H), 7.56 (s, 1H), 7.32 (t, *J* = 7.3 Hz, 1H), 7.28 (t, *J* = 7.3 Hz, 1H).

4-Benzo[b]thiophen-2-ylbenzaldehyde (4)[1]
From 4-bromobenzaldehyde (0.185 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **4** was obtained in 72% (0.171 g) yield. ^1H NMR (400 MHz, $CDCl_3$): δ 9.97 (s, 1H), 7.87 (d, *J* = 8.3 Hz, 2H), 7.80 (d, *J* = 8.3 Hz, 2H), 7.80-7.72 (m, 2H), 7.63 (s, 1H), 7.32 (t, *J* = 7.3 Hz, 1H), 7.28 (t, *J* = 7.3 Hz, 1H).

1-(4-Benzo[b]thiophen-2-yl-phenyl)-ethanone (5)[1]
From 4-bromoacetophenone (0.199 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **5** was obtained in 66% (0.166 g) yield. ^1H NMR (400 MHz, $CDCl_3$): δ 7.93 (d, *J* = 8.3 Hz, 2H), 7.80-7.68 (m, 4H), 7.59 (s, 1H), 7.30 (t, *J* = 7.3 Hz, 1H), 7.27 (t, *J* = 7.3 Hz, 1H), 2.55 (s, 3H).

Ethyl 4-benzo[b]thiophen-2-yl-benzoate (6)[7h]
From ethyl 4-bromobenzoate (0.229 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **6** was obtained in 76% (0.214 g) yield. ^1H NMR (400 MHz, $CDCl_3$): δ 8.01 (d, *J* = 8.3 Hz, 2H), 7.74 (d, *J* = 7.0 Hz, 1H), 7.70-7.65 (m, 3H), 7.56 (s, 1H), 7.30 (t, *J* = 7.3 Hz, 1H), 7.27 (t, *J* = 7.3 Hz, 1H), 4.32 (q, *J* = 7.2 Hz, 2H), 1.34 (t, *J* = 7.2 Hz, 3H).

2-(4-Chlorophenyl)-benzo[b]thiophene (7)[7h]
From 1-bromo-4-chlorobenzene (0.191 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **7** was obtained in 73% (0.178 g) yield. ^1H NMR (400 MHz, $CDCl_3$): δ 7.76 (d, *J* = 7.0 Hz, 1H), 7.70 (d, *J* = 7.0 Hz, 1H), 7.56 (d, *J* = 8.3 Hz, 2H), 7.44 (s, 1H), 7.32 (d, *J* = 8.3 Hz, 2H), 7.30-7.20 (m, 2H).

2-(4-Fluorophenyl)-benzo[b]thiophene (8)[7h]
From 1-bromo-4-fluorobenzene (0.175 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **8** was obtained in 80% (0.182 g) yield. ^1H NMR (400 MHz, $CDCl_3$): δ 7.73 (d, *J* = 7.7 Hz, 1H), 7.68 (d, *J* = 7.7 Hz, 1H), 7.58 (dd, *J* = 8.6, 4.8 Hz, 2H), 7.37 (s, 1H), 7.27 (t, *J* = 7.3 Hz, 1H), 7.23 (t, *J* = 7.3 Hz, 1H), 7.03 (t, *J* = 8.6 Hz, 2H).

2-(4-Methylphenyl)-benzo[b]thiophene (9)[7l]
From 4-bromotoluene (0.171 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **9** was obtained in 55% (0.123 g) yield. ^1H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, *J* = 7.8 Hz, 1H), 7.68 (d, *J* = 7.8 Hz, 1H), 7.53 (d, *J* = 8.3 Hz, 2H), 7.42 (s, 1H), 7.26 (t, *J* = 7.3 Hz, 1H), 7.23 (t, *J* = 7.3 Hz, 1H), 7.20 (d, *J* = 8.3 Hz, 2H), 2.32 (s, 3H).

2-(4-*tert*-Butylphenyl)-benzo[b]thiophene (10)[7h]
From 1-*tert*-butylbromobenzene (0.213 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **10** was obtained in 32% (0.085 g) yield. ^1H NMR (400 MHz, $CDCl_3$): δ 7.73 (d, *J* = 7.8 Hz, 1H), 7.67 (d, *J* = 7.8 Hz, 1H), 7.53 (d, *J* = 8.3 Hz, 2H), 7.42 (s, 1H), 7.36 (d, *J* = 8.3 Hz, 2H), 7.24 (t, *J* = 7.3 Hz, 1H), 7.21 (t, *J* = 7.3 Hz, 1H), 1.27 (s, 9H).

2-(3-Cyanophenyl)-benzo[b]thiophene (11)[13a]
From 3-bromobenzonitrile (0.182 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **11** was obtained in 60% (0.141 g) yield. ^1H NMR (400 MHz, $CDCl_3$): δ 7.88 (s, 1H), 7.81 (d, *J* = 7.9 Hz, 1H), 7.76 (d, *J* = 7.8 Hz, 1H), 7.71 (d, *J* = 7.8 Hz, 1H), 7.51 (d, *J* = 7.9 Hz, 1H), 7.50 (s, 1H), 7.43 (t, *J* = 7.8 Hz, 1H), 7.30 (t, *J* = 7.3 Hz, 1H), 7.27 (t, *J* = 7.3 Hz, 1H).

2-*m*-Tolylbenzo[b]thiophene (12)[13b]
From 3-bromotoluene (0.171 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **12** was obtained in 60% (0.134 g) yield. ^1H

NMR (400 MHz, $CDCl_3$): δ 7.75 (d, *J* = 7.7 Hz, 1H), 7.69 (d, *J* = 7.5 Hz, 1H), 7.50-7.40 (m, 3H), 7.25-7.20 (m, 3H), 7.08 (d, *J* = 7.4 Hz, 1H), 2.34 (s, 3H).

2-Naphthalen-2-yl-benzo[b]thiophene (13)[7h]
From 2-bromonaphthalene (0.207 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **13** was obtained in 62% (0.161 g) yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.07 (s, 1H), 7.85-7.70 (m, 6H), 7.60 (s, 1H), 7.47-7.37 (m, 2H), 7.29 (t, *J* = 7.8 Hz, 1H), 7.23 (t, *J* = 7.3 Hz, 1H).

2-Benzo[b]thiophen-2-yl-benzonitrile (14)
From 2-bromobenzonitrile (0.182 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **14** was obtained in 73% (0.171 g) yield as a white solid (mp 119-121 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80-7.72 (m, 3H), 7.67 (d, *J* = 7.7 Hz, 1H), 7.59 (d, *J* = 7.8 Hz, 1H), 7.52 (t, *J* = 7.3 Hz, 1H), 7.36-7.23 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.3, 140.2, 139.2, 137.5, 134.5, 133.0, 130.2, 128.2, 125.3, 124.8, 124.5, 124.4, 122.1, 118.7, 110.5. elemental analysis: calcd (%) for $C_{15}H_9NS$ (235.30): C 76.56, H 3.86; found: C 76.65, H 4.02.

2-Naphthalen-1-ylbenzothiophene (15)[7l]
From 1-bromonaphthalene (0.207 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **15** was obtained in 82% (0.213 g) yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.18 (d, *J* = 8.0 Hz, 1H), 7.83-7.75 (m, 3H), 7.73 (d, *J* = 7.6 Hz, 1H), 7.54 (d, *J* = 7.0 Hz, 1H), 7.45-7.22 (m, 6H).

2-Anthracen-9-yl-benzo[b]thiophene (16)[13c]
From 9-bromoanthracene (0.257 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **16** was obtained in 83% (0.257 g) yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.49 (s, 1H), 7.99 (d, *J* = 8.4 Hz, 2H), 7.90-7.82 (m, 4H), 7.45-7.30 (m, 7H).

5-Benzo[b]thiophen-2-yl-pyrimidine (17)
From 5-bromopyrimidine (0.159 g, 1 mmol) and benzothiophene (0.201 g, 1.5 mmol), **17** was obtained in 66% (0.140 g) yield as a white solid (mp 128-130 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.09 (s, 1H), 8.95 (s, 2H), 7.79 (d, *J* = 7.7 Hz, 1H), 7.75 (d, *J* = 7.5 Hz, 1H), 7.56 (s, 1H), 7.32 (t, *J* = 7.4 Hz, 1H), 7.29 (t, *J* = 7.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.8, 153.9, 140.1, 139.9, 136.1, 128.7, 125.5, 125.1, 124.2, 122.5, 121.9. elemental analysis: calcd (%) for $C_{12}H_8N_2S$ (212.27): C 67.90, H 3.80; found: C 67.99, H 3.64.

4-(3-Formylbenzo[b]thiophen-2-yl)-benzonitrile (18)[8a]
From 4-bromobenzonitrile (0.182 g, 1 mmol) and benzothiophene-3-carbaldehyde (0.243 g, 1.5 mmol), **18** was obtained in 65% (0.171 g) yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.97 (s, 1H), 8.71 (d, *J* = 8.1 Hz, 1H), 7.81 (d, *J* = 7.9 Hz, 1H), 7.75 (d, *J* = 8.4 Hz, 2H), 7.64 (d, *J* = 8.4 Hz, 2H), 7.48 (t, *J* = 7.3 Hz, 1H), 7.42 (t, *J* = 7.3 Hz, 1H).

2-(3-Nitrophenyl)-benzo[b]thiophene-3-carbaldehyde (19)
From 3-bromonitrobenzene (0.202, 1 mmol) and benzothiophene-3-carbaldehyde (0.243 g, 1.5 mmol), **19** was obtained in 78% (0.221 g) yield as a yellow solid (mp 136-138 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.99 (s, 1H), 8.72 (d, *J* = 8.1 Hz, 1H), 8.40 (d, *J* = 1.7 Hz, 1H), 8.32 (d, *J* = 8.3 Hz, 1H), 7.85 (d, *J* = 8.4 Hz, 1H), 7.82 (d, *J* = 8.4 Hz, 1H), 7.4867 (t, *J* = 7.3 Hz, 1H), 7.50 (t, *J* = 7.3 Hz, 1H), 7.45 (t, *J* = 7.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 185.4, 156.3, 148.4, 138.2, 136.8, 136.2, 133.4, 131.1, 130.0, 126.7, 126.5, 125.4, 125.1, 124.6, 121.8. elemental analysis: calcd (%) for $C_{15}H_9NO_3S$ (283.30): C 63.59, H 3.20; found: C 63.42, H 3.04.

2-(3-Formylbenzo[b]thiophen-2-yl)-benzonitrile (20)[8a]
From 2-bromobenzonitrile (0.182 g, 1 mmol) and benzothiophene-3-carbaldehyde (0.243 g, 1.5 mmol), **20** was obtained in 77% (0.202 g) yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.83 (s, 1H), 8.71 (d, *J* = 8.1 Hz, 1H), 7.81 (d, *J* = 7.8 Hz, 1H), 7.79 (d, *J* = 7.8 Hz, 1H), 7.67 (t, *J* = 7.8 Hz, 1H), 7.60-7.55 (m, 2H), 7.49 (t, *J* = 7.3 Hz, 1H), 7.43 (t, *J* = 7.3 Hz, 1H).

2-Isoquinolin-4-yl-benzo[b]thiophene-3-carbaldehyde (21)
From 4-bromoisoquinoline (0.208 g, 1 mmol) and benzothiophene-3-carbaldehyde (0.243 g, 1.5 mmol), **21** was obtained in 65% (0.188 g) yield as a yellow solid (mp 132-134 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.67 (s, 1H), 9.32 (s, 1H), 8.76 (d, *J* = 8.1 Hz, 1H), 8.61 (s, 1H), 8.02 (d, *J* = 7.6 Hz, 1H), 7.83 (d, *J* = 7.6 Hz, 1H), 7.79 (d, *J* = 7.6 Hz, 1H), 7.64 (t, *J* = 7.6 Hz, 1H), 7.62 (t, *J* = 7.7 Hz, 1H), 7.50 (t, *J* = 7.6 Hz, 1H), 7.43 (t, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 185.8, 154.4, 154.1, 144.6, 139.0, 136.4, 135.3, 133.1, 132.0, 128.2, 128.1, 126.6, 126.3, 125.3, 124.3, 121.7. elemental analysis: calcd (%) for $C_{18}H_{11}NOS$ (289.35): C 74.72, H 3.83; found: C 74.60, H 3.98.

2-Pyrimidin-5-yl-benzo[b]thiophene-3-carbaldehyde (22)
From 5-bromopyrimidine (0.159 g, 1 mmol) and benzothiophene-3-carbaldehyde (0.243 g, 1.5 mmol), **22** was obtained in 61% (0.146 g) yield as a yellow solid (mp 151-153 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 10.00 (s, 1H), 9.30 (s, 1H), 8.94 (s, 2H), 8.70 (d, *J* = 8.1 Hz, 1H), 7.83 (d, *J* = 8.1 Hz, 1H), 7.50 (t, *J* = 8.1 Hz, 1H), 7.44 (t, *J* = 8.1 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 184.6, 159.3, 157.0, 150.7, 138.4, 136.8, 131.7, 126.9, 126.7, 125.3, 121.9. elemental analysis: calcd (%) for $C_{13}H_8N_2OS$ (240.28): C 64.98, H 3.36; found: C 65.14, H 3.47.

4-(3-Methylbenzo[b]thiophen-2-yl)-benzonitrile (23)
From 4-bromobenzonitrile (0.182 g, 1 mmol) and 3-methyl-benzothiophene (0.222 g, 1.5 mmol), **23** was obtained in 88% (0.219 g) yield as a white solid (mp 125-127 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76 (d, *J* = 7.5 Hz, 1H), 7.67 (d, *J* = 7.8 Hz, 1H), 7.64 (d, *J* = 8.4 Hz, 2H), 7.55 (d, *J* = 8.4 Hz, 2H), 7.36 (t, *J* = 7.3 Hz, 1H), 7.30 (t, *J* = 7.3 Hz, 1H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.0, 139.6, 139.1, 135.7, 132.3, 130.2, 129.4, 125.2, 124.6, 122.6, 122.3, 118.7, 111.3, 12.8. elemental analysis: calcd (%) for $C_{16}H_{11}NS$ (249.33): C 77.07, H 4.45; found: C 77.01, H 4.35.

Ethyl 4-(3-methylbenzo[b]thiophen-2-yl)-benzoate (24)
From ethyl 4-bromobenzoate (0.229 g, 1 mmol) and 3-methyl-benzothiophene (0.222 g, 1.5 mmol), **24** was obtained in 81% (0.240 g) yield as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.05 (d, *J* = 8.2 Hz, 2H), 7.76 (d, *J* = 7.5 Hz, 1H), 7.67 (d, *J* = 7.8 Hz, 1H), 7.54 (d, *J* = 8.2 Hz, 2H), 7.35 (t, *J* = 7.3 Hz, 1H), 7.29 (t, *J* = 7.3 Hz, 1H), 4.34 (q, *J* = 7.1 Hz, 2H), 2.41 (s, 3H), 1.34 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.3, 141.1, 139.3, 139.1, 136.8, 129.8, 129.6, 129.5, 128.6, 124.7, 124.3, 122.4, 122.2, 61.1, 14.4, 12.8. elemental analysis: calcd (%) for $C_{18}H_{16}O_2S$ (296.38): C 72.94, H 5.44; found: C 72.80, H 5.32.

2-(4-Chlorophenyl)-3-methylbenzo[b]thiophene (25)
From 1-bromo-4-chlorobenzene (0.191 g, 1 mmol) and 3-methyl-benzothiophene (0.222 g, 1.5 mmol), **25** was obtained in 88% (0.227 g) yield as a white solid (mp 87-89 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, *J* = 7.5 Hz, 1H), 7.64 (d, *J* = 7.8 Hz,

1H), 7.39 (d, *J* = 8.2 Hz, 2H), 7.34 (d, *J* = 8.2 Hz, 2H), 7.31 (t, *J* = 7.3 Hz, 1H), 7.27 (t, *J* = 7.3 Hz, 1H), 2.36 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.1, 138.9, 136.7, 133.9, 133.2, 130.9, 128.8, 127.9, 124.5, 124.3, 122.2, 122.1, 12.6. elemental analysis: calcd (%) for $C_{15}H_{11}ClS$ (258.77): C 69.62, H 4.28; found: C 69.79, H 4.09.

3-Methyl-2-*m*-tolyl-benzo[b]thiophene (26)
From 3-bromotoluene (0.171 g, 1 mmol) and 3-methylbenzothiophene (0.222 g, 1.5 mmol), **26** was obtained in 66% (0.157 g) yield as a colourless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72 (d, *J* = 7.8 Hz, 1H), 7.61 (d, *J* = 7.9 Hz, 1H), 7.35-7.18 (m, 5H), 7.10-7.05 (m, 1H), 2.36 (s, 3H), 2.32 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.3, 138.9, 138.3, 138.2, 134.7, 130.4, 128.6, 128.5, 127.3, 126.9, 124.3, 124.1, 122.2, 122.1, 21.5, 12.7. elemental analysis: calcd (%) for $C_{16}H_{14}S$ (238.35): C 80.63, H 5.92; found: C 80.74, H 5.99.

2-(3-Methylbenzo[b]thiophen-2-yl)-benzonitrile (27)
From 2-bromobenzonitrile (0.182 g, 1 mmol) and 3-methylbenzothiophene (0.222 g, 1.5 mmol), **27** was obtained in 79% (0.197 g) yield as a white solid (mp 122-124 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75 (d, *J* = 7.5 Hz, 1H), 7.70 (d, *J* = 7.8 Hz, 1H), 7.68 (d, *J* = 7.8 Hz, 1H), 7.56 (t, *J* = 7.8 Hz, 1H), 7.48 (d, *J* = 7.2 Hz, 1H), 7.41 (t, *J* = 7.3 Hz, 1H), 7.36 (t, *J* = 7.3 Hz, 1H), 7.31 (t, *J* = 7.3 Hz, 1H), 2.30 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.3, 139.6, 138.4, 133.3, 133.1, 132.5, 132.0, 131.2, 128.6, 125.1, 124.5, 122.7, 122.2, 117.9, 113.9, 13.0. elemental analysis: calcd (%) for $C_{16}H_{11}NS$ (249.33): C 77.07, H 4.45; found: C 77.40, H 4.57.

3-(3-Methylbenzo[b]thiophen-2-yl)-pyridine (28)
From 3-bromopyridine (0.158 g, 1 mmol) and 3-methylbenzothiophene (0.222 g, 1.5 mmol), **28** was obtained in 70% (0.157 g) yield as a white solid (mp 210-212 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.73 (d, *J* = 1.2 Hz, 1H), 8.53 (d, *J* = 3.6 Hz, 1H), 7.80-7.70 (m, 2H), 7.66 (d, *J* = 8.0 Hz, 1H), 7.40-7.23 (m, 3H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 150.2, 148.8, 140.9, 139.1, 136.8, 133.9, 130.9, 129.0, 124.8, 124.4, 123.4, 122.4, 122.2, 12.6. elemental analysis: calcd (%) for $C_{14}H_{11}NS$ (225.31): C 74.63, H 4.92; found: C 74.57, H 4.69.

4-(3-Methylbenzo[b]thiophen-2-yl)-isoquinoline (29)
From 4-bromoisoquinoline (0.208 g, 1 mmol) and 3-methylbenzothiophene (0.222 g, 1.5 mmol), **29** was obtained in 61% (0.168 g) yield as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.24 (s, 1H), 8.53 (s, 1H), 7.99 (d, *J* = 8.0 Hz, 1H), 7.81 (d, *J* = 7.7 Hz, 1H), 7.75-7.70 (m, 2H), 7.65-7.55 (m, 2H), 7.40 (t, *J* = 7.8 Hz, 1H), 7.33 (t, *J* = 7.8 Hz, 1H), 2.16 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.0, 144.8, 140.4, 139.9, 135.2, 131.9, 131.3, 131.0, 128.3, 128.0, 127.5, 125.9, 125.0, 124.7, 124.4, 122.3, 122.2, 12.7. elemental analysis: calcd (%) for $C_{18}H_{13}NS$ (275.37): C 78.51, H 4.76; found: C 78.51, H 4.87.

4-(5-Chloro-3-methylbenzo[b]thiophen-2-yl)-benzonitrile (30)
From 4-bromobenzonitrile (0.182 g, 1 mmol) and 5-chloro-3-methylbenzothiophene (0.274 g, 1.5 mmol), **30** was obtained in 78% (0.221 g) yield as a white solid (mp 164-166 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70-7.63 (m, 4H), 7.56 (d, *J* = 8.3 Hz, 2H), 7.27 (d, *J* = 8.5 Hz, 1H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 142.1, 139.0, 137.7, 137.2, 132.4, 130.9, 130.2, 128.7, 125.5, 123.3, 122.2, 118.6, 111.7, 12.8. elemental analysis: calcd (%) for $C_{16}H_{10}ClNS$ (283.78): C 67.72, H 3.55; found: C 67.81, H 3.41.

1-[4-(5-Chloro-3-methylbenzo[b]thiophen-2-yl)-phenyl]-propan-1-one (31)
From 4-bromopropiophenone (0.213 g, 1 mmol) and 5-chloro-3-methylbenzothiophene (0.274 g, 1.5 mmol), **31** was obtained in 83% (0.261 g) yield as a white solid (mp 136-138 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.94 (d, *J* = 8.3 Hz, 2H), 7.62-7.58 (m, 2H), 7.51 (d, *J* = 8.3 Hz, 2H), 7.27 (d, *J* = 8.5 Hz, 1H), 2.91 (q, *J* = 7.5 Hz, 2H), 2.34 (s, 3H), 1.16 (t, *J* = 7.5 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 200.1, 142.4, 138.8, 137.1, 136.1, 130.7, 129.7, 128.3, 128.1, 125.1, 123.2, 122.1, 31.9, 12.8, 8.3. elemental analysis: calcd (%) for $C_{18}H_{15}ClOS$ (314.83): C 68.67, H 4.80; found: C 68.49, H 4.89.

5-Chloro-2-(4-chlorophenyl)-3-methylbenzo[b]thiophene (32)
From 1-bromo-4-chlorobenzene (0.191 g, 1 mmol) and 5-chloro-3-methylbenzothiophene (0.274 g, 1.5 mmol), **32** was obtained in 85% (0.249 g) yield as a white solid (mp 137-138 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.60 (d, *J* = 8.2 Hz, 1H), 7.58 (s, 1H), 7.40-7.30 (m, 4H), 7.20 (d, *J* = 8.3 Hz, 1H), 2.30 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 142.4, 138.7, 136.9, 134.2, 132.7, 130.9, 130.7, 128.9, 127.4, 124.9, 123.2, 121.9, 12.6. elemental analysis: calcd (%) for $C_{15}H_{10}Cl_2S$ (293.21): C 61.44, H 3.44; found: C 61.59, H 3.31.

2-(4-*tert*-Butylphenyl)-3-methyl-benzo[b]thiophene (33)
From 1-*tert*-butylbromobenzene (0.213 g, 1 mmol) and 5-chloro-3-methylbenzothiophene (0.274 g, 1.5 mmol), **33** was obtained in 58% (0.182 g) yield as a white solid (mp 134-136 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.64 (d, *J* = 8.2 Hz, 1H), 7.60 (s, 1H), 7.45-7.35 (m, 4H), 7.22 (d, *J* = 8.3 Hz, 1H), 2.36 (s, 3H), 1.30 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 151.2, 142.6, 140.3, 136.9, 131.3, 130.4, 129.3, 126.6, 125.6, 124.4, 123.1, 121.7, 34.8, 31.3, 12.6. elemental analysis: calcd (%) for $C_{19}H_{20}ClS$ (314.87): C 72.47, H 6.08; found: C 72.27, H 6.29.

5-Chloro-3-methyl-2-(3-nitrophenyl)-benzo[b]thiophene (34)
From 3-bromonitrobenzene (0.202, 1 mmol) and 5-chloro-3-methylbenzothiophene (0.274 g, 1.5 mmol), **34** was obtained in 83% (0.251 g) yield as a yellow solid (mp 176-177 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.30 (s, 1H), 8.16 (d, *J* = 8.3 Hz, 1H), 7.75 (d, *J* = 7.7 Hz, 1H), 7.68-7.60 (m, 2H), 7.57 (t, *J* = 8.0 Hz, 1H), 7.26 (d, *J* = 8.5 Hz, 1H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 148.4, 142.1, 137.0, 136.0, 135.5, 131.0, 129.7, 128.7, 125.5, 124.3, 123.3, 122.8, 122.2, 12.6. elemental analysis: calcd (%) for $C_{15}H_{10}ClNO_2S$ (303.76): C 59.31, H 3.32; found: C 59.50, H 3.48.

5-Chloro-3-methyl-2-*m*-tolyl-benzo[b]thiophene (35)
From 3-bromotoluene (0.171 g, 1 mmol) and 5-chloro-3-methylbenzothiophene (0.274 g, 1.5 mmol), **35** was obtained in 80% (0.218 g) yield as a colourless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.58 (d, *J* = 8.3 Hz, 1H), 7.56 (s, 1H), 7.30-7.05 (m, 5H), 2.31 (s, 3H), 2.30 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 142.6, 140.4, 138.4, 137.0, 134.2, 130.5, 130.3, 128.9, 128.6, 126.8, 126.7, 124.6, 123.1, 121.8, 21.5, 12.7. elemental analysis: calcd (%) for $C_{16}H_{13}ClS$ (272.79): C 70.45, H 4.80; found: C 70.32, H 4.68.

5-Chloro-3-methyl-2-naphthalen-2-yl-benzo[b]thiophene (36)
From 2-bromonaphthalene (0.207 g, 1 mmol) and 5-chloro-3-methylbenzothiophene (0.274 g, 1.5 mmol), **36** was obtained in 88% (0.271 g) yield as a white solid (mp 128-129 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.85 (s, 1H), 7.80-7.70 (m, 3H), 7.65-7.55 (m, 2H), 7.51 (d, *J* = 8.3 Hz, 1H), 7.43-7.38 (m, 2H), 7.19 (d, *J* = 8.4 Hz, 1H), 2.34 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 142.6,

140.2, 137.2, 133.3, 132.8, 131.7, 130.6, 128.9, 128.3, 128.2, 127.8, 127.3, 127.2, 126.7, 126.6, 124.7, 123.2, 121.9, 12.8. elemental analysis: calcd (%) for $C_{19}H_{13}ClS$ (308.83): C 73.89, H 4.24; found: C 74.08, H 4.01.

2-(5-Chloro-3-methyl-benzo[b]thiophen-2-yl)-benzonitrile (37)
From 2-bromobenzonitrile (0.182 g, 1 mmol) and 5-chloro-3-methylbenzothiophene (0.274 g, 1.5 mmol), **37** was obtained in 82% (0.232 g) yield as a white solid (mp 161-163 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71 (d, *J* = 8.3 Hz, 1H), 7.68-7.60 (m, 2H), 7.58 (t, *J* = 7.7 Hz, 1H), 7.50-7.40 (m, 2H), 7.25 (d, *J* = 8.6 Hz, 1H), 2.25 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.5, 137.8, 137.6, 135.1, 133.4, 132.6, 131.9, 130.8, 130.6, 128.9, 125.5, 123.2, 122.4, 117.8, 113.8, 12.9. elemental analysis: calcd (%) for $C_{16}H_{10}ClNS$ (283.78): C 67.72, H 3.55; found: C 67.57, H 3.59.

3-(5-Chloro-3-methylbenzo[b]thiophen-2-yl)-pyridine (38)
From 3-bromopyridine (0.158 g, 1 mmol) and 5-chloro-3-methylbenzothiophene (0.274 g, 1.5 mmol), **38** was obtained in 76% (0.197 g) yield as a white solid (mp 116-118 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.58 (d, *J* = 1.1 Hz, 1H), 8.52 (d, *J* = 3.8 Hz, 1H), 7.69 (d, *J* = 7.9 Hz, 1H), 7.60-7.55 (m, 2H), 7.27 (dd, *J* = 7.7, 4.9 Hz, 1H), 7.20 (dd, *J* = 8.5, 1.8 Hz, 1H), 2.30 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 150.1, 149.2, 142.1, 137.1, 136.7, 136.0, 130.8, 130.4, 128.4, 125.1, 123.4, 123.2, 122.1, 12.5. elemental analysis: calcd (%) for $C_{14}H_{10}ClNS$ (259.75): C 64.73, H 3.88; found: C 64.50, H 3.99.

2-(3-Bromobenzothiophen-2-yl)-benzonitrile (39)
From 2-bromobenzonitrile (0.182 g, 1 mmol), 3-bromo-benzothiophene (0.319 g, 1.5 mmol), KOAc (0.196 g, 2 mmol) at 150 °C during 16 h in DMAc (4 mL) in the presence of $Pd(OAc)_2$ (1.12 mg, 0.005 mmol), **40** was obtained in 62% (0.195 g) yield as a brown solid (mp 174-176 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.83 (d, *J* = 8.0 Hz, 1H), 7.77 (d, *J* = 8.0 Hz, 1H), 7.75 (d, *J* = 8.0 Hz, 1H), 7.63 (td, *J* = 7.7, 1.1 Hz, 1H), 7.55 (d, *J* = 7.2 Hz, 1H), 7.49 (td, *J* = 7.7, 1.1 Hz, 1H), 7.45 (t, *J* = 7.7 Hz, 1H), 7.39 (t, *J* = 7.7 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 138.6, 138.1, 136.7, 133.8, 133.5, 132.6, 132.0, 129.4, 126.2, 125.6, 124.1, 122.3, 117.5, 114.0, 109.1. elemental analysis: calcd (%) for $C_{15}H_8BrNS$ (314.20): C 57.34, H 2.57; found: C 57.50, H 2.86.

4-[2-(4-Chlorophenyl)-benzo[b]thiophen-3-yl]-benzonitrile (40)
From 2-(4-chlorophenyl)-benzothiophene **7** (0.244 g, 1 mmol), 4-bromobenzonitrile (0.364 g, 2 mmol), KOAc (0.392 g, 4 mmol) at 150 °C during 20 h in DMAc (4 mL) in the presence of $PdCl(C_3H_5)$(dppb) (3.1 mg, 0.005 mmol) **40** was obtained in 47% (0.162 g) yield as a white solid (mp 178-180 °C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.82 (d, *J* = 7.0 Hz, 1H), 7.64 (d, *J* = 8.3 Hz, 2H), 7.46 (d, *J* = 7.0 Hz, 1H), 7.37 (d, *J* = 8.3 Hz, 2H), 7.35-7.25 (m, 2H), 7.19 (d, *J* = 8.5 Hz, 2H), 7.12 (d, *J* = 8.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.3, 139.8, 139.7, 139.0, 134.5, 132.6, 132.0, 131.6, 131.2, 130.9, 128.9, 125.2, 125.0, 122.8, 122.4, 118.7, 111.4. elemental analysis: calcd (%) for $C_{21}H_{12}ClNS$ (345.85): C 72.93, H 3.50; found: C 72.80, H 3.66.

Supporting information

Copies of ^{1}H and ^{13}C NMR spectra of new compounds.

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